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Powerful non-geoeffective interplanetary disturbance of July 2012 observed by muon hodoscope URAGAN

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Abstract

The most powerful coronal mass ejection of the 24th solar cycle took place on the opposite side of the Sun on July 23, 2012 and had no geomagnetic consequences. Nevertheless, as a result of passing of the ejection through the heliosphere, variations of galactic cosmic rays flux were observed on the Earth. These variations were registered by the muon hodoscope URAGAN (MEPhI, Moscow). Muon flux angular distributions on the Earth's surface are reported and analyzed.

Keywords: CME; Muon hodoscope URAGAN; Cosmic ray

1. Introduction

Investigation of the processes on the Sun, including coronal mass ejections (CME), is generally carried out by means of detectors placed on spacecrafts and ground based observatories. During the decades of the spacecraft operation, a huge amount of experimental material has been accumulated and various relationships between the processes occurring on the Sun, in the heliosphere and magnetosphere of the Earth have been established, but a complete picture of the influence of solar activity on the Earth and near-Earth space cannot be built because the available information is of a point character and is limited by the position of the detector in space.

In July 2012 the large-scale coronal mass ejections, which source was the sunspot 1520, occurred. On July 12th the X-class solar flare, which was oriented towards the Earth and caused strong disturbances in the Earth's magnetosphere on July 14th, occurred. The subsequent events from the same region of the Sun, which were non-geoeffective as the sunspot 1520 moved to the opposite side from the Earth, are of a special interest. The first non-geoeffective CME occurred on July 17, 2012 after a M-class flare and was registered by the SOHO spacecraft. The second CME occurred on July 23 and was detected by the STEREO A spacecraft. The speed of the CME on July 23 reached ~3000 km/s (Russell et al., 2013). Both ejections were not oriented towards the Earth and had negligible influence on it, as well as on its magnetosphere and atmosphere.

Cosmic rays are a powerful tool for indirect investigations of the heliosphere and its dynamics (Dorman et al., 2004). An analysis of the data of the muon hodoscope (MH) URAGAN which registered the muon flux angular distribution variations due to galactic cosmic ray flux variations that arise as a result of the passage of these CME through the heliosphere is presented in this paper.

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2. Conditions in the interplanetary space near the Earth in July 2012

Let us first consider the events on the Sun in the chronological order. CME of July 17 occurred after a flare, which was registered by the SOHO spacecraft at the Lagrange point L1 at 17:15 UT. The passage of the ejection through the heliosphere has been simulated by the Goddard Space Weather Lab (Model Goddard Space Weather Lab, 2014). According to the forecast track prepared by the analysts at the Goddard Space Weather Lab, the CME would hit Venus on July 19 and could deliver a glancing blow to the Earth on July 20. According to the simulation, CME left the observed area on July 22. The snapshot of the Goddard Space Weather Lab simulation for the July 20 2012 12:00 UT is shown in Fig. 1. It is seen that the Venus is in the CME passage sector, while the Earth is on the sectors border, so CME could have an impact on the near-Earth space only by the peripheral part.

The launch of CME of July 23 was registered at 02:08 (±2 min) by EUVI imager of the STEREO-A spacecraft (Russell et al., 2013). The snapshot of the Goddard Space Weather Lab simulation for the July 24 2012 12:00 UT is shown in Fig. 2. At this time CME reached the Earth orbit. Worth noting that only STEREO-A was in this sector of the heliosphere and the other satellites and planets of the solar system were in the opposite sectors. CME left the observed area on July 27.

Let us now consider the geomagnetic conditions and the state of the interplanetary space in the vicinity of the Earth's orbit from July 10 to August 10. Data on the disturbance of the interplanetary magnetic field, solar wind parameters and geomagnetic activity indices (OMNI Database, 2014) are presented in Fig. 3. The magnetic storm (Kp > 6, Dst < −100 nT), caused by the solar flare on July 12, was observed on July 14–15. Periods of the subsequent CME that occurred after the transition of the sunspot to the other side from the Earth are marked by vertical lines. Fig. 3 shows the absence of strong disturbances in the near-Earth space and magnetosphere in this period.

3. Apparatus and experimental data

Muon hodoscope URAGAN (Barbashina et al., 2008) (55.7°N, 37.7°E, 173 m above sea level) is the coordinate detector that allows to investigate the variations of the muon flux angular distribution on the Earth's surface. Registered muons with threshold energies from 0.2 to 0.4 GeV retain the direction of the primary particles motion, which allows to study primary cosmic rays in the interplanetary space. URAGAN consists of four independent supermodules (SM) with total area of ~46 m^2. Each SM is assembled of eight layers of gas-discharge chambers (streamer tubes) equipped with two-coordinate system of external readout strips and provides a high spatial and angular accuracy of muon track detection (correspondingly, 1 cm and 1°) in a wide range of zenith angles. Data are accumulated by minute intervals and contain matrices of two-dimensional angular distribution of the muon flux.

To study the MH URAGAN integral counting rate, 10-min data summed over all modules and corrected for the barometric and temperature effects are used (Dmitrieva et al., 2013).

For the study of two-dimensional variations of muon flux registered by the muon hodoscope URAGAN, a local anisotropy vector (Shutenko et al., 2013) which is the sum of the unit vectors of particle tracks normalized by the total number of tracks is used. Its absolute value is of the order

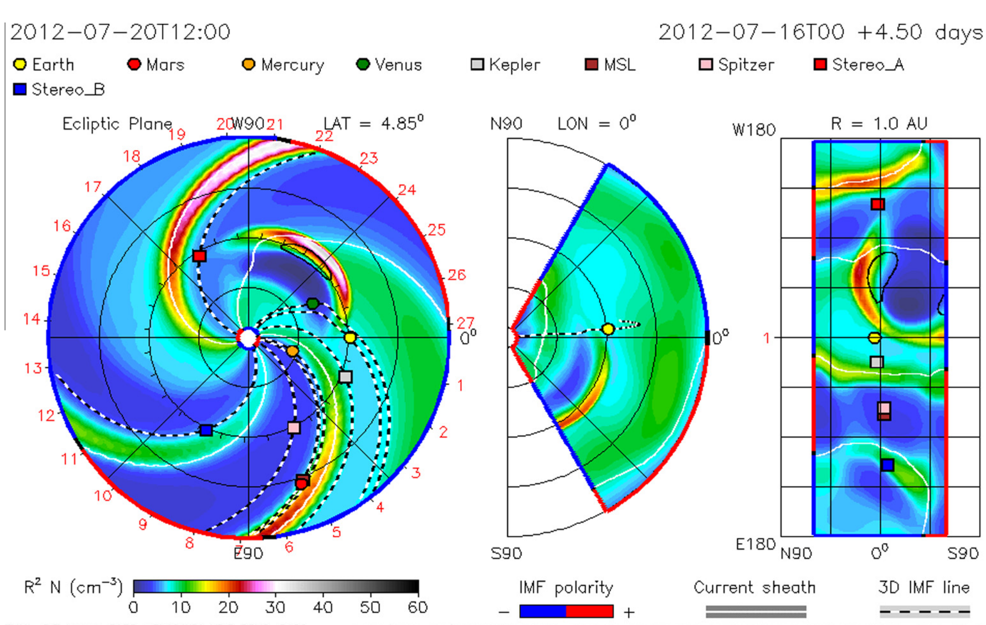

Fig. 1. Snapshot of Goddard Space Weather Lab simulation on July 20 2012 at 12:00 UT.